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LOW-REFLECTION COATINGS OF THE OPTICAL PARTS OF THE VICTORIA STELLAR SPECTROGRAPH*

By A. McKELLAR and C. S. BEALS

ABSTRACT

Measurements have been made of the relative transmissions of eight spectrographic lenses before and after coating with magnesium fluoride. The measurements have been made with the aid of a photronic cell and a galvanometer. The results have shown that, for the 40 coated surfaces, the average gain in transmission per surface, throughout the visible region, is 3.3 per cent.

In the last decade, great advances have been made in the problem of reducing the reflections at air-glass and glass-air optical surfaces. Although many years ago[1-3] it was noted that "bloom" on the surfaces of lenses sometimes increased their transmission, it was not until Miss Blodgett, Strong, Cartwright and others took up the problem some 10 years ago that a really satisfactory solution of the problem was found. Since then, a considerable literature on the subject has been built up. References to a number of articles, but by no means all, that have been published, are given below.[4-13]

*Contributions from the Dominion Astrophysical Observatory, No. 8.

[1]Harold Dennis Taylor, *The Adjustment and Testing of Telescope Objectives* (T. Cook, York, England, 1896).

[2]F. Kollmorgen, *Trans. Soc. Ill. Eng.*, vol. 11, p. 220, 1916.

[3]F. E. Wright, *Ordnance Dept. Document no. 2037 (U.S.A.)*, p. 76.

[4]K. B. Blodgett, *J. Am. Chem. Soc.*, vol. 57, p. 1007, 1935.

[5]J. Strong, *J. Opt. Soc. Am.*, vol. 26, p. 73, 1936.

[6]K. B. Blodgett and I. Langmuir, *Phys. Rev.*, vol. 51, p. 964, 1937.

[7]K. B. Blodgett, *J. Phys. Chem.*, vol. 41, p. 975, 1937.

Clean glass surfaces reflect 4 to 7 per cent. (depending on the nature of the glass) of the light normally incident upon them. It has been found that if a layer of suitable material of the correct thickness is deposited on the glass surface, the reflection can be reduced to the order of 1 per cent. or less. If n is the index of refraction of the glass and $n^{1/2}$ that of the coating material, and if the optical thickness of the coating is one-quarter of the wave-length of the incident light, the reflection is theoretically reduced to zero. A case for two superimposed quarter-wave films has also been studied. Here the reflection is reduced to zero if $n_2 = (n_1 n_3^2)^{1/2}$ where n_1 is the index of refraction of the glass, n_2 the index for the bottom layer and n_3 the index of the top layer. The elementary theory for the single-layer case is summarized by Greeland[16] while the exact treatment for both cases is given by Mooney[17].

In practice it has been found that a layer of magnesium fluoride, or of cryolyte (sodium-aluminum fluoride), indices of refraction 1.38 and 1.36 respectively at λ5890, having thickness one-quarter the wave-length of green light, gives a substantial reduction in surface reflections. The reduction extends throughout the wide, useful region from the ultra-violet to the near infra-red (2000 to 10,000 Angstrom units).

The application of such coatings to the glass surfaces may be done in various ways. Chemical means of producing films of some substances (for example, barium stearate[6]) have been developed. However, the technique most generally used has been evaporation in vacuum, similar to the method used in depositing thin reflecting coats of aluminum, etc. A material much employed for non-reflecting films is magnesium fluoride, which is reasonably durable

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[9]C. H. Cartwright and A. F. Turner, *Phys. Rev.*, vol. 55, p. 675 (Abst.), 1939.
[9]K. B. Blodgett, *Phys. Rev.*, vol. 55, p. 391, 1939.
[10]C. H. Cartwright, *J. Opt. Soc. Am.*, vol. 30, p. 110, 1940.
[11]F. L. Jones and J. Homer, *J. Opt. Soc. Am.*, vol. 31, p. 34, 1941.
[12]British Scientific Instrument Research Assn., *British Patent* 538, 273, July 28, 1941.
[13]F. H. Nicoll, *R.C.A. Review*, vol. 6, p. 287, 1942.
[14]C. H. Cartwright and A. F. Turner, *U.S. Patent* 2, 281, 474, April 28, 1942.
[15]A. Smakula, *Physik. Zeit.*, vol. 43, p. 217, 1942.
[16]K. M. Greenland, *Nature*, vol. 152, p. 290, 1943.
[17]R. L. Mooney, *J. Opt. Soc. Am.*, vol. 35, p. 574, 1945.
[18]P. King and L. B. Lockhart, *J. Opt. Soc. Am.*, vol. 36, p. 513, 1946.

when deposited with proper techniques. The process has been referred to as "fluoriding" or "blooming."

The desirability of reducing losses by reflection was immediately obvious to astronomers, particularly those working in the field of stellar spectroscopy. While a gain of about 3 per cent. for one surface does not seem impressive, when this gain is applied to each air-glass or glass-air surface in an optical train containing a number of such surfaces, the increase in transmission can be considerable. The average single-prism spectrograph has about eight such surfaces, so reflection losses alone reduce the light reaching the photographic plate to 78 per cent. of that entering the slit. Also, the presence in the instrument of this scattered light can, and doubtless does, have a detrimental effect on its performance. In his report for 1939-1940, the director of the Mount Wilson Observatory described a new spectrograph[19] and stated that the transmitting surfaces in the entire optical system had been treated with an evaporated coat of fluorite with a marked gain in light efficiency. He indicated that the surfaces of the prisms and lenses in other stellar spectrographs would be similarly treated. Two spectrographs of the Lick Observatory, each having 14 air-glass surfaces, were treated with non-reflecting coats in 1941. For these two, increases in light transmission of slightly over 100 per cent. and of 120 per cent. were reported by Mayall and Wyse[20]. Their measurements were carried out by a photographic method. At the David Dunlap Observatory, the combination of aluminizing the two telescope mirrors and coating the optical surfaces of the spectrograph with low-reflecting films, has been reported by Young[21] to have accounted for a large gain in speed. The gain was such that with the 25-inch camera the spectrograph became, throughout the ordinary photographic region, somewhat faster than it previously had been with the 12.5-inch camera. This gain was probably largely due to the aluminizing but no doubt an appreciable fraction may be attributed to the coating of the optical surfaces.

At the Dominion Astrophysical Observatory, the question of using non-reflecting films was considered some years ago and pre-

[19] "Annual Report of the Director of the Mount Wilson Observatory"—*Carnegie Institution of Washington Year Book*, no. 39, for the year 1939-1940, p. 15.

[20] *Pub. Ast. Soc. Pac.*, vol. 53, p. 120, 1941.

[21] *Pub. David Dunlap Obs.*, vol. 1, p. 311, 1945.

liminary plans were made as early as 1941 to construct a small vacuum chamber for carrying out the process. However, certain war activities interfered with these plans. By the time the matter was taken up again in 1945, a number of firms had acquired experience in depositing the coatings on a commercial scale. It was accordingly decided to have the optical parts coated by such a firm rather than to set up equipment for the process. The work was entrusted to Duplate Canada Limited and was done under the supervision of Dr. S. Bateson during the early part of 1946. The material used was magnesium fluoride and the coating was applied to all air-glass surfaces of the spectrographic prisms and lenses. Certain of the lens surfaces which have been oil-cemented were, of course, not done.

In order to measure the transmission of the lenses before and after the fluoride coating was applied the following equipment was employed. The source of light was the 6-volt lamp used in the observatory's microphotometer, operated from two batteries in parallel. The lamp contains a projection lens built into its housing. The light from this lamp passed through an "Aklo" filter to absorb the infra-red radiation and then through a circular diaphragm to remove any extraneous light. The lens to be tested was behind this diaphragm and formed an image of the lamp's projection lens on the sensitive surface of a Weston photronic cell. The cell was connected to a Cambridge Instrument Company "Pot" galvanometer, the deflections of which were measured. The transmissions of the spectrographic lenses were measured by comparing the deflections when they were in the optical system with the deflections when they were replaced first by one and then the other of two lenses used in the laboratory. These two "standards" were (1) a simple quartz lens of aperture 5.4 cm. and focal length 14 cm. and (2) a glass lens of 8.8 cm. aperture and 17 cm. focal length. Neither of these lenses has fluorided surfaces.

The results of the measurements, given in the accompanying table, are the transmissions of the several lenses relative to that of the glass lens (2) referred to in the previous paragraph. The effective wave-length range is governed by the nature of the light source, the filter used and the sensitivity curve of the photronic cell. While no precise determination has been made the maximum is in the vicinity of λ5800 with effective limits approximately λ3900 and λ6500. The

TRANSMISSIONS OF THE SPECTROGRAPH LENSES

Designation of Lens	Aperture	Focal Length	Number of Components	Number of Surfaces Fluorided	Transmission*		Ratio of Transmission after Fluoriding to Transmission Before	Percentage Increase in Transmission per Surface	Remarks
					Before Fluoriding	After Fluoriding			
1. Spectrograph Collimator.....	63 mm.	1143 mm.	3	2	1.14	1.23	1.08	3.9	Brashear triplet, interfaces oil cemented.
2. Moffit Lens.....	76	228	4	8	0.89	1.13	1.27	3.0	
3. SS Camera Lens.	76	225	4	8	0.89	1.12	1.26	2.9	
4. S Camera Lens..	76	381	3	4	1.03	1.23	1.19	4.4	Cooke triplet, one interface oil cemented.
5. M Camera Lens.	76	711	3	2	1.12	1.21	1.08	3.9	Brashear triplet, interfaces oil cemented.
6. L Camera Lens..	76	940	3	2	1.11	1.23	1.11	5.4	Brashear triplet, interfaces oil cemented.
7. Ross Lens.....	76	711	4	8	0.82	1.10	1.34	3.7	
8. Zeiss Astro Triplet Lens.....	79	970	3	6	0.97	1.08	1.12	1.9	

*This transmission is relative to the uncoated glass lens (f = 17 cm.) mentioned in the text.

figures in the eighth column of the table indicate that the lenses having eight surfaces had their transmissions increased about 30 per cent. The overall average increase in transmission per surface coated was 3.3 per cent. Hence for the one-prism form of the stellar spectrograph with the SS camera, where there are twelve coated surfaces, the speed is increased by about 50 per cent. With the six prism Littrow form of the spectrograph (16 surfaces) the gain is a little greater and with simpler combinations is somewhat less. It is clear that the fluoriding process has resulted in a substantial increase in the efficiency of the telescope-spectrograph combination, to say nothing of the decrease in scattered light, so desirable, especially for the spectrophotometric phases of the observatory's work.

Dominion Astrophysical Observatory,
Victoria, B.C.
November 17, 1946.

AURORE BOREALE DU 26 JUILLET 1946, VENANT DU SUD

Vendredi soir, le 26 juillet 1946, pendant plus d'une heure et pour la deuxième fois de ma vie, j'ai observé une aurore venant du sud.

Ce soir-là, j'étais à la campagne, à Ste-Thérèse de Blainville, comté de Terrebonne, Qué., (paroisse située à environ 20 milles au nord de Montréal) lorsque, à 10 heures 15 m. du soir (heure avancée), je vis apparaitre dans le ciel un immense et blanchâtre cercle lumineux, de la largeur d'un arc-en-ciel, s'élever à l'horizon est, près d'Altaïr de l'Aigle, passer par le zénith près de Véga et redescendre vers l'horizon ouest près d'Eta de la Grande Ourse, séparant ainsi la voûte céleste en deux hémisphères. Le ciel était d'une grande pureté et d'un calme absolu.

Rien de plus étrange que cette vision d'un arc-en-ciel nocturne, pendant que, dans tout le reste du ciel, aucun indice d'une apparition prochaine d'aurore. Pendant une dizaine de minutes cet arc demeura immobile et d'une égale intensité lumineuse.

A 10 h. 30 m. (h.av.) partant de l'horizon sud, un voile lumineux en doubles teintes, jaune crême à gauche et rose à droite, comme un immense voile de soie translucide, s'étendit sur le ciel, demeura quelques instants immobile, puis, graduellement et lentement se dirigea vers l'ouest, pour de nouveau d'immobiliser en-dessous d'Arcturus du Bouvier.

Cet immense voile de lumière d'une transparence merveilleuse, en passant vis-à-vis de Jupiter, manifesta sa double teinte d'une manière encore plus prononcée. La couleur rose présentait une telle intensité, que l'on aurait cru à un immense et lointain incendie.

Quelques instants après cette merveilleuse féérie, de l'horizon est à l'horizon nord-ouest apparut une clarté laiteuse, clarté semblable à la lueur précédent le lever du soleil. Dans cette mer lumineuse flottaient de noirs nuages, nuages très allongés dont l'ensemble présentait l'aspect d'un ciel nordique. Il y eût un moment d'accalmie, puis, au-dessus de l'horizon N.N.O., dans une nouvelle mer de lumière composée des deux teintes mentionnées plus haut, apparurent encore des nuages sombres ayant cette fois l'aspect de bizarres et fantastiques monstres de la période Triasique.

Pendant que j'observais et que je notais ces aspects successifs à 10 h. 50 m. (heure avancée) je vis à l'horizon ouest, un spectacle nouveau. Traversant et enveloppant Jupiter, une immense et large colonne blanchâtre, d'une luminosité intense, s'éleva vers les hauteurs du ciel. Phénomène d'une originalité et d'une splendeur telle, que cela me remémora à l'esprit le phénomène de la colonne lumineuse qui guida les Hébreux dans le désert. Cette colonne, inclinée d'environ 15° vers le sud, d'une largeur d'au moins 7°, présentait un aspect étrange et fantastique! Cette vision merveilleuse dura environ cinq minutes.

Immédiatement après, du carré de Pégase à Alpha de la Grande Ourse, de l'horizon jusqu'au zénith, à l'exception de l'horizon nord, tout le ciel s'embrasa d'une immense lueur qui forma un dôme gigantesque de lumière. A travers cette grande luminosité, qui se déplaçait lentement, l'on voyait spontanément apparaître, ici et là, des jets luminuex allant se concentrer au zénith, près de Véga, et former ensuite un noeud d'une mobilité incessante.

A 11 h. 00 m. (h.av.) l'intensité lumineuse augmenta sur tout le pourtour de l'horizon sud, de l'est à l'ouest et comme précédemment, des rayons jaillirent un peu partout, se multiplièrent, s'intensifièrent pour aller ensuite se concentrer vers le zénith où ils formèrent de nouveau un noeud de lumière d'une grande mobilité.

De 11 h. 15 m. à 11 h. 30 m. la manifestation grandiose diminua d'intensité, les rayons diminuèrent d'éclat, et, peu à peu, le phénomène se résolva en une étendue diffuse et pâle sur tout l'ensemble du ciel pour ne laisser subsister qu'une vague lueur crépusculaire.

Les deux jours précédents, ayant observé la grande tache solaire, je m'attendais un peu à une manifestation aurorale, mais jamais d'une manière aussi spectaculaire. Cette aurore venant du sud fut, pour moi, l'un des plus beaux spectacles jamais vu précédemment. C'est l'un de ces phénomènces que l'on oublie jamais!

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J. Edgar Guimont.

SIDERITE METEORITES AND THEIR CHEMISTRY

By R. P. Graham

(Concluded from page 143)

Structure of Siderites

Information of very considerable interest relative to the structure of siderites is obtained as a result of etching a freshly-cut and finely-polished section of an iron meteorite with a suitable reagent.* In perhaps most cases this treatment will reveal a pattern of intersecting bands, called a Widmanstätten** or Widmanstetter figure (figure 4). In other siderites a pattern of long fine parallel lines, called Neumann† lines (figure 5), may become apparent; in still others no regular pattern of any kind appears. A definite etch figure, often best studied using a microscope with a vertical illuminator, indicates the presence of uniformity of structure in the meteorite. Siderites which do not exhibit an etch pattern have no regular structure; such meteorites are called ataxites.

The Widmanstätten patterns consist of comparatively wide bands of kamacite normally bordered by narrow taenite lamellae, with the areas between the banding commonly consisting of plessite. The bands are parallel to octahedral planes and hence meteorites showing this pattern are called octahedrites (the pattern is octahedral, but the iron present is cubic in crystallization). Octahedrites, depending on the width of the kamacite bands, are divided into several sub-classes, viz. coarsest (Ogg) in which the bands are 2.5 mm. or wider, coarse (Og), medium (Om), fine (Of), and finest (Off) in which the bands are narrower than 0.2 mm. The width of the kamacite band in an octahedrite is related to its nickel content; a relatively high value

*The etching reagent attacks the various minerals present with differing rates of reaction and thus causes portions of the surface to stand out in relief. The metallographic techniques for the polishing and etching, etc., of siderite meteorites have been given in considerable detail by Perry[86] together with notes relating to methods of studying and observing the etch patterns. Relevant material has been also furnished by Nininger.[70]

**Alois von Widmanstätten, Director of the Imperial Porcelain Works in Vienna, discovered the phenomenon in 1808.

†J. Neumann first discovered the lines, in 1848.

of the latter is associated with a narrow kamacite band. Explanations of these facts based on studies of the iron-nickel system have been advanced.[80,86] There is some disagreement regarding the range of nickel contents found in octahedrites (e.g., see[22,27,34,37,46,80, 82,87,99,113]), but the variation is roughly from six to thirteen or fourteen per cent.[54]

The coarsest octahedrites would appear to shade into the hexahedrite class of siderite in which the single structural component is kamacite.* As in the case of the octahedrites there is not unanimity of opinion as regards the concentration of nickel appropriate to a hexahedrite (e.g., see[22,27,34,37,46,80,87,99]) but certainly it is within the range of five to seven per cent. Hexahedrites usually show a well-defined cubic cleavage, and generally exhibit Neumann lines on etching; Neumann lines are not, however, a unique characteristic of hexahedrites—they are known to be exhibited by octahedrites and by certain ataxites, and in some hexahedrites the lines are absent or essentially so. Granular (or brecciated) hexahedrites are characterized by visible macrograins; normal hexahedrites are unigrain crystals. Hexahedrites (and also ataxites) are much less common than octahedrites.

The ataxites, or siderites showing neither cleavage, Neumann lines, nor Widmanstätten pattern, may have nickel contents comparable to or below that of the hexahedrites or above that of the finest octahedrites; the two classes are distinguished by referring to ataxites as either nickel-poor (which rarely if ever have a concentration below five per cent.) or nickel-rich (the highest concentration of nickel ever found is sixty-two per cent.). There appears to be no sharp line of demarkation between the finest octahedrites and the nickel-rich ataxites.** Ataxites may have resulted from the granulation of other types of siderites by secondary heating,[34,37,65] perhaps by approach to the sun when they were too small to permit a repetition of a slow cooling process.[84] Perry[86] considers that nickel-poor (but not nickel-rich) ataxites have resulted from a process of cosmic reheating.

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*In the section of this paper dealing with the structure of siderites much use has been made of the valuable treatment of "The Metallography of Meteoric Iron" by Perry.[86]

**As Thomas Graham, the father of colloid chemistry, pointed out in 1861, "distinctions of class are never absolute."[41]

A number of studies (e.g.,[13,14,23,24,25,27,55,61,62,80,81,86,99,108] and references given therein) with artificial iron-nickel alloys have been undertaken with a view to gaining a better understanding of the structure of siderites. If the conditions that give rise to the formation of kamacite, taenite, and plessite and their inter-relationships can be understood, then much will have been learned not only about the origin of the Widmanstätten and Neumann patterns, but also regarding the thermal history of the siderites. These studies are made difficult by very sluggish transitions (or slow rates at which reactions may occur in the solid state) in significant regions of the phase diagram of iron and nickel, by the existence of metastable states, and by the fact that the rate of cooling markedly affects the temperature at which iron changes from one crystal form to another. Such complications have led to some diverse and erratic results. Although much progress has been made in this field,[60] the equilibrium diagram of the iron-nickel system is still not definitely established. The presence in siderites of accessory elements such as cobalt, phosphorus, sulfur, and carbon, complicates the metallurgical study of meteorites, but some understanding of the role of these elements has been achieved.

Kamacite, the main component of siderites, is α–iron (which has a body-centred cubic lattice) carrying up to a maximum of about six per cent. of nickel in solid solution. Taenite, which contains varying proportions of nickel (vide supra) but with the concentration always higher than that in kamacite, has the γ–iron structure (face-centred cubic lattice), which crystal structure is stable at high temperatures.[62] Whether the nickel in taenite is present always as a solid solution[99] as seems probable, or whether an intermetallic compound of the type Fe_3Ni or Fe_2Ni may be present,[17,37] is not entirely clear. It is very possible[86] that the nickel content of taenite depends on the temperature at which it segregated and the rate at which it cooled. There seems to be general agreement (e.g.,[25,62,80,86,99], but cf.[107,108]) that the kamacitic (or α) structure has arisen in siderites from the γ form of iron as a result of a solid-solid transformation, but the mechanism of this reaction and the thermal conditions necessary for it are not as yet definitely established. The physical properties, and the orientations of the kamacite and taenite in siderites, as

well as the inter-relationships of these orientations, have been studied (e.g., [24,34,49,61,63,80,86,99]).

The coarse Widmanstätten patterns found in octahedrites and the essentially unigrain (single crystal) character of siderites would strongly suggest that iron meteorites have a history involving an extremely slow rate of cooling[22,23,24,25,62,84,86,89] from a high temperature (e.g.,1400°C.[25] or a liquid melt[113]), perhaps within the central core of some body of planetary dimensions.[37,99,113] On the other hand the view has been expressed, also on the basis of metallurgical evidence, that the Widmanstätten pattern may be developed as a result of a process involving a stage of rapid cooling,[55,80,107] but mechanisms involving rapid cooling are perhaps not very probable.[24,86]

It has been suggested[73,80] that the Widmanstätten structure may have arisen as a result of repeated heat-treatment and annealing operations—it being assumed that the meteorite travelled in a cometary orbit and approached close to the sun and receded to the outer parts of the solar system many times during its history. This view has been subjected to criticism both on physico-chemical[86] and other[86,113] grounds. It is thus seen that there still remain considerable differences of opinion regarding the genesis of the Widmanstätten pattern.

If a siderite meteorite in which a Widmanstätten pattern is evident (i.e., an octahedrite) is heated to a high temperature (800°C.,[113] 850°C.[101] or 1000°C.[89]), the Widmanstätten pattern is found to have been modified[37] or to have disappeared,[69] and a granular structure remains.[65] (Neumann lines also are readily obliterated by heat). This gives us some understanding of why certain octahedrites do not show a well-developed Widmanstätten pattern complete to the surface edges of the meteorite;[34,69,98] the surface portion of the latter has been heated during atmospheric flight to a temperature sufficiently high to alter or destroy the structure of the meteorite in this region. Siderites other than octahedrites also show such a zone of alteration due to terrestrial heating.[86] It may be mentioned that, by means of suitable heat treatments, Widmanstätten patterns similar in type to those exhibited by octahedrite siderites have been induced in synthetic iron-nickel alloys;[11,24,25,61,62] these artificial patterns are, however, very much smaller than those exhibited by octahedrite meteorites.

It should be noted also that internal stresses or strains in certain metallic systems,[30] produced perhaps by violent disruptive explosions[37] or sudden impact with some other body,[24] or by rapid quenching from a high temperature[79] are conducive to the growth and development of large single crystals from fine-grained aggregates. The possible relevance of these facts to the study of the origin and history of siderites, and in particular the development[24,37] of the Neumann lines in hexahedrites, should not be overlooked. It is considered by Perry[80] that the Neumann lines in meteorites are the result of violent stresses caused by atmospheric pressure during flight.

Although a very considerable amount of study and research in physical metallurgy and physical chemistry remain to be done before our understanding of the structure of siderite meteorites can be considered to be at all a satisfactory one, our knowledge of this subject is almost constantly growing.

Origin of Siderite Meteorites

A variety of proposals have been put forth in an attempt to explain the origin of meteorites. For example, some have suggested that they may be the result of volcanic action on the moon (or even on the earth!), others have regarded meteorites as having grown in space through the accumulation of small portions of solid material. Edmund Halley at one time considered that fireballs might originate in the atmosphere from 'sulphureous vapours.' All such theories are now of course regarded as untenable. The present paper is concerned almost entirely with siderites, but it should be pointed out that the modern chemical, physical, mineralogical and metallurgical study of meteorites in general has not furnished evidence inconsistent with the view that meteorites represent fragments of some disintegrated mass which was comparable in size to the earth.[113]

Although the evidence is not yet definitive, and unanimity of opinion has not yet been achieved, the work of chemists and metallurgists on the structure of octahedrite siderites suggests[113] that the material from which these meteorites originated was at some time at a very high temperature,* and was later subjected to a process of

*There is geochemical evidence[75] to suggest that meteorites have condensed from the gaseous phase.

prolonged cooling.[37,89] That high temperatures were involved in the formation of siderites may also be inferred from the presence of carbide and phosphide minerals,[102] and additional evidence indicating a slow cooling rate is the existence of veins in at least certain siderite meteorites.[24] The presence of diamonds in some siderites points to the existence of conditions of high pressure[21,113] at some time (perhaps when the melt was cooling[73]) in the history of these meteorites.** The presence of water-reactive chemical constituents such as phosphides and carbides[37] and metallic iron[89] indicate that siderites were formed in the absence of water, and the presence of phosphides indicates an absence of free oxygen where they were formed.[31,34] Thus we may think of siderite meteorites as having originated under conditions involving the prolonged cooling from a high temperature of some large mass, that conditions of high pressure may have existed, and that water almost certainly was absent.

Authorities in the field of geology are agreed[21,22,37] that the core of the earth is composed essentially of iron and nickel, and it has been noted earlier that these two elements constitute almost the entire mass of a siderite. If we tentatively accept a catastrophic origin for meteorites,[37] then it seems fair to assume that siderite meteorites originated† from the core of this ancestral planet.

No element unknown on the earth has been found in meteorites, and almost all the elements occurring on the earth have been detected in meteorites. Detailed geochemical studies involving scores of elements have been carried out, notably by V. M. Goldschmidt[39,40] and by I. and W. Noddack,[74,75,76,77] relating the abundance of the elements in meteorites to that in the earth. Paneth notes[84] that the abundance of the elements and their distribution amongst the main constituents of the meteorites "is just what might be expected if we assume that the composition of the original magma was very similar in both cases and only the geological history different—the earth showing a more advanced differentiation than the meteorites." The isotopic abundance ratios for a number of elements have been studied with the source material from both meteoritic and terrestrial matter;

**It should be mentioned, however, that the finding of some diamonds bordering a cavity in a meteorite[73] does not lend support to the conclusion.

†The view has been expressed[65] that the iron of siderites was formed as a result of the reduction of ferrous chloride. This seems most unlikely.

the ratios are independent of the origin. Helium studies show that the age of some siderites is of the order of a few billion years, as is the age of the earth. These facts do not make it necessary to infer that meteorites originated within the solar system, but they furnish no evidence to support a theory of interstellar origin. The case for the latter rests on the study of the velocities of certain fireballs; velocities indicating hyperbolic orbits have been computed,[78] but it should be noted that there is reason to question[110,116] the validity of these velocity calculations.* And even if some meteorites should be definitely proven to have hyperbolic orbits, this would not make necessary the assumption of an interstellar origin for the meteorites unless it were proven that the hyperbolic velocity was original and not the result of perturbations.[84]

Many able students of meteoritics accept the view that meteorites have originated within the solar system, and that they are parts of some body of planetary dimensions that became disintegrated[21,22,34, 37,50,64,113] by explosion, or by a collision, or by the gravitational force that would cause disruption if this hypothetical planet passed very close (i.e., within the Roche limit) to a large body like Jupiter at some time.** On this hypothesis, meteorites are to be regarded as "the débris of some celestial catastrophe," as planetic fragments that wandered in inter-planetary space until they entered our atmosphere to enjoy a few brief seconds of blazing glory before plunging to rest on the surface of the earth. Some writers have identified[22] this postulated progenitor of the meteorites as the missing planet of Olbers. If one is willing to relate meteorites and asteroids, as some have done, [22,84,113] then the large number of asteroids or planetoids in the region

*In this connection the possible use of radar in tracing the paths of meteorites should be mentioned. The meteor shower encountered October 9-10, 1946, during the passage of the earth through the orbit of the Giacobini-Zinner Comet, was studied by radar methods both in Great Britain (Nature, vol. 158, p. 936, 1946) and in the United States (Science, vol. 104, p. 434, 1946). Actually, the investigation of echoes caused by the reflection of radio pulses from meteor trails has been carried on in Britain since 1932; these scientific experiments laid the basis for the development of practical radar.

**An explosion or collision probably would give rise to sufficient heat to destroy the Widmanstätten structure. The tidal disintegration theory is therefore preferable;[84] this would allow disruption without the generation of great heat—thus the fragments would have a good chance of retaining the structure developed in the parent body.

between the orbits of Mars and Jupiter[113] lends support to this view.

It is worth noting that from a comparison of the number of meteorites known to fall in the afternoon with the number falling in the morning, the conclusion has been drawn by Paneth[84] that the majority of meteorites move in the same direction round the sun as does the earth; calculations by Watson[111] indicate that the same is true in the case of the majority of the meteor streams. The relationship that one might be tempted to adduce from these findings is contra-indicated by the observation that no meteorite has been identified as coming from any known meteor shower,[65,113] with possibly one exception.[34,87,117] The inter-relationships that may exist between asteroids, comets, meteor streams and showers, and individual meteorites are not clearly understood.[113]

It is of course recognized that the question "whence came the meteorites?" is one primarily for the astronomer. But chemists, together with mineralogists, physical metallurgists, petrologists, physicists, geochemists, and geophysicists, are applying microscopes, spectrographs, Geiger-Müller counters, mass spectrometers, the methods of microchemical and X-ray analysis, and other instruments and techniques to the study of these celestial visitors. The data from these researches should serve to delimit the field for fruitful astronomical enquiry regarding the origin of the meteorites.

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NORTH STAR OBSERVATORY

By E. K. White

It is with pleasure that I can announce the completion of my private observatory situated at my home in Kimberley, B.C. It is called the "North Star Observatory" and houses a nine-inch Newtonian equatorial reflector of one hundred inches focal length. The telescope is equipped with circles including a slip-ring R.A. circle on the main worm wheel, electric clock drive, finder, solar projection screen and a dozen eyepieces giving powers from 75X to 850X. This observatory is the highest in all Canada, the elevation of the floor being 3600 feet above sea level.

Fig. 1.—General View of the Observatory.

Planetary and lunar investigations will be carried on as in the past when the same telescope was housed under a roll-off shelter. Visits from travelling amateurs are welcome. The dome is only a few blocks from the Banff-Windermere Highway, running from Cranbrook, B.C.

The dome is 15 feet in diameter and is fastened rigidly to a circular wall 5 feet high and 15 feet in diameter. The whole building revolves on a curved angle-iron track running on eight grooved wheels mounted on an eighteen-foot-diameter concrete floor. The wall consists of two complete cedar rings two-ply thickness, three inches wide, each separated by thirty-two 1½ inch by 2 inch spruce studs 4 feet long fastened at 16 inch intervals. This frame is wrapped with sheets of ¼-inch three-ply resin-bonded fir veneer. The dome consists of eighteen gores and a shutter frame 43 inches wide extending 10 inches beyond the dome's centre. The ribs are of two-ply cedar 3 inches wide, shutter frames being 6 inches wide. The dome is sheathed with ¼-inch veneer and the seams are covered with a concave wood batten. The shutter doors are the double transverse type, covered with Masonite board. They open simultaneously by means of an endless flexible cable-and-pulley system.

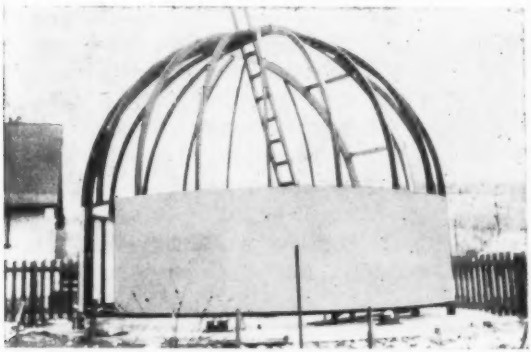

Fig. 2.—Showing construction of the Dome.

The whole observatory is dismountable, no nails being used; but seventeen gross of screws and several hundred bolts and corner brackets were employed in construction. The outside was given three coats of white paint and the inside was finished in flat black. The dome revolves with very little friction and will be a highly satisfactory housing for the telescope and the observer while he is using the instrument.

In figures 1 and 2 are shown two views of the observatory.

THE NEPTUNE CENTENARY*

On the evening of 1946 October 8 a conversazione was held in the rooms of the Royal Astronomical Society in Burlington House to celebrate the centenary of the discovery of Neptune. The year 1946 also marks the tercentary of the birth of John Flamsteed†, first Astronomer Royal, and the quatercentenary of the birth of Tycho Brahe, the Danish astronomer whose precise observations were used by Kepler in deriving his laws of planetary motion; and the opportunity was taken to celebrate also these occasions.

After a formal reception by the Officers of the Society and their ladies, a large gathering of Fellows and invited guests inspected a collection of exhibits connected with Tycho, Flamsteed, Adams and Le Verrier. These included a number of portraits of these famous astronomers, copies of their printed works, their manuscript letters, and (in the case of the first two) drawings and engravings of their instruments and observatories.

An entertaining and instructive lecture by Prof. W. M. Smart, entitled "John Couch Adams and the Discovery of Neptune," proved so popular that it had to be delivered twice during the evening. The president of the society, Prof. H. H. Plaskett, introduced Prof. Smart as the first John Couch Adams Astronomer and invited him to tell the audience of his researches into the history of the Neptune discovery.

Reminding his hearers of the accidental discovery of Uranus in 1781 and the subsequent search for other planets, rewarded during the next sixty-five years by the discovery of only five minor planets, Prof. Smart went on to put the Neptune discovery on an entirely different level, resulting as it did from mathematical predictions made by two brilliant young men, Adams in England and Le Verrier in France. Not all the history has yet been published, and Prof. Smart, who has access to Adams's private papers, threw fresh light on the well-known story with many illuminating references. After thumb-nail sketches of the others who figured in the affair— Airy, the Astronomer Royal at the time; Challis, his meek and uncertain successor at Cambridge;

*From *The Observatory*, vol. 66, p. 378, 1946 (December 1946).

†Flamsteed, Aug. 19, 1646—Dec. 31, 1719; see this JOURNAL, vol. 41, p. 25, 1947. Tycho Brahe, Dec. 14, 1546—Oct. 14, 1601—Editorial Note.

and Le Verrier, brilliant young French astronomer—the lecturer told how the pre-discovery observations of Uranus (the first, incidentally, by Flamsteed in 1690) gave a different orbit from the observations made after the planet had been watched for some years. Soon, he said, it became apparent that the planet was falling behind its predicted position. By 1832 the error in longitude was 0'.5; in 1837 Airy remarked that the errors were "increasing with fearful rapidity." In 1844 Airy suggested that perhaps Newton's law of gravitation was not quite accurate. If the perturbations were due to another planet, he stated his opinion that "it will be very nearly impossible ever to find out its place." Fortunately, said Prof. Smart, Adams and Le Verrier had a better conception of the task and more confidence in the power of mathematical analysis.

At this point the lecturer sketched the early life of Adams. A brilliant boy, though by no means a bookworm, he showed his mathematical ability early and went to Cambridge, where, at St. John's, he read Airy's report on the discrepancies in the motion of Uranus and resolved in 1841 to explain them, if possible, by the attraction of a trans-Uranian planet whose place he proposed to calculate. Two years later, now, at twenty-four, Senior Wrangler and a fellow of his college, he started work. Within a year a first solution had convinced him of the adequacy of his hypothesis, and in the next eighteen months he refined his solution to such an extent that in 1845 September he was ready to put it to the test of observation. Furnished by Challis with a letter of introduction to Airy, he went to Greenwich, only to learn that the Astronomer Royal was abroad. A month later (1845 October 21) a second attempt to see Airy also proved fruitless, and Adams returned to Cambridge disappointed, leaving a short statement of his results at the Royal Observatory. A fortnight later Airy wrote to Adams with a query which Adams regarded as too trivial to be worth answering, and Airy did nothing further for eight months.

Meanwhile, in Paris, Le Verrier had been working along the same lines as Adams, though nobody in England was aware of the fact. In 1845 November he read a first memoir on the motion of Uranus which made, however, no mention of a hypothetical external planet. In 1846 June his second memoir announced the place of a disturbing body which would account for the perturbations—a posi-

tion within 1° of that found by Adams. This remarkable agreement stirred Airy to action. He reported it to his Board of Visitors at the end of June, and on July 9 wrote to Challis at Cambridge suggesting a search of the region of the sky indicated. The work—a laborious search for a moving object in a part of the sky for which neither Greenwich nor Cambridge possessed a suitable chart—began on July 29, and by the end of September Challis had made over 3000 observations, three of them (unwittingly) of the new planet. But meanwhile Le Verrier's third memoir had been presented to the Academy and its author, having received no reply to an earlier appeal to Airy for practical assistance in the search, had written to Berlin giving his prediction. The letter was received on September 23, and that very night Galle, the assistant at the Berlin Observatory, helped by a young student named d'Arrest, who suggested the use of Bremiker's newly-completed chart of the region, discovered the planet within a degree of the predicted place.

Into the ensuing atmosphere of rejoicing in France, said Prof. Smart, Sir John Herschel's letter to the *Athenaeum* making the first public reference to Adams's work came as a bombshell. Then followed the most celebrated and perhaps one of the bitterest scientific controversies of the age, involving claims and counter-claims for priority in the prediction of the new planet, in its discovery and in the right to name it. Few of the leading figures emerge in a particularly favourable light: Airy's treatment of Adams was vigorously criticized by many people, though he has perhaps been unfairly attacked; Challis's part was that of a sceptic and procrastinator; Le Verrier and his chief Arago showed an irascibility only partly justified by the facts. Only Adams declined to engage in the controversy, and he never made any reproaches in spite of a number of slights suffered at the hands of his fellow-countrymen. As to the question of priority, in this centenary year we do not need to try to settle this arid point; rather do we hail Adams and Le Verrier as equal sharers in one of the greatest triumphs of science.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

Chinese Observations of Solar Spots

Most of our readers are familiar with the fact that the Chinese records of sun-spots go back much earlier than the invention of the telescope in Europe; but probably few have any idea of the Chinese source of the records, or the dates on which naked-eye sun-spots were recorded. Accordingly we reprint below an article from *Monthly Notices*, Royal Astronomical Society, vol. xxxiii, p. 370, 1873, entitled *Chinese Observations of Solar Spots* by Mr. John Williams.

Having lately become possessed of a copy of the celebrated Encyclopaedia of Ma Twan Lin, I found, on examining the astronomical sections of that work, a considerable number of observations of solar spots, extending over a period of 904 years, and, considering that some account of these ancient observations might be of interest to the Society, I have requested permission to lay before you a translation of them, in the hope that they may be of some service to such of the Fellows as may be more particularly engaged in the investigation of these peculiar phenomena.

The Encyclopaedia of Ma Twan Lin is considered not only by the Chinese themselves, but also by such European Sinologists as have had occasion to refer to it, as a most remarkable and trustworthy work. Many eminent writers speak of it in the highest terms of approbation, and among these I take the opportunity of calling your attention to the opinion of Abel Remusat, the author of a well-known and excellent Chinese grammar, who, after giving in that work, an account of a number of the best Chinese works on different subjects, concludes thus:—"And above all, the excellent work of Ma Twan Lin, entitled *Wan Heen Tung Kao*, the finest monument of Chinese literature, a vast collection of memoirs on all sorts of subjects, a treasure of erudition and criticism, in which all the materials that Chinese antiquity has left us, relating to their religion, legislation, rural and political economy, commerce, agriculture, government, natural history, physical geography, and ethnology, will be found, brought together, classed and discussed, in admirable order, method, and lucidity,—in short, a production which, as I have had occasion before to remark elsewhere, is in itself a complete library, and which, did their literature offer nothing else of value, would deserve that the Chinese language should be acquired, were it for no other purpose than to read this work."

My copy of this highly esteemed work is in 100 Chinese volumes. The matters treated of are arranged under 24 principal heads. These are divided into 348 sections or chapters, which have also numerous subdivisions. The astronomical portion consists of 17 chapters, Nos. 278 to 295 inclusive. The subjects treated of are—The general distribution of the stars in the heavens,

comprising the asterisms in the three great spaces and the twenty-eight stellar divisions, the whole of which are enumerated and fully described; thus forming a complete Chinese catalogue of stars.

The degrees and mansions of the twelve zodiacal divisions follow, and it may be here observed that the ancient Chinese zodiacal names alone are given. The course of the Milky Way comes next, followed by a general account of the Sun, Moon, and five planets. Next we have extraordinary appearances in the stars and in the heavens generally; these, however, consist principally of accounts of halos and vapours or extraordinary configurations of the clouds.

These are followed by a long account of eclipses of the Sun, commencing with that recorded in the Shoo King, said to have occurred B.C. 2158, of which I gave an account in the *Monthly Notices*, vol. xxiii, and ending with one in A.D. 1223, the number being more than 600; some account of these may, if agreeable to the Society, form the subject of a future communication. We have next extraordinary appearances connected with the Sun, among which are the observations of solar spots, which form the subject of the present paper. These are followed by eclipses of the Moon and singular appearances connected with that body. Next are observations of comets. These have been translated in the work I lately published on Chinese Comets. Prognostications or astrological deductions from the motions and positions of the heavenly bodies come next, followed by observations of shooting or other moving stars; they extend from the Chow dynasty, which commenced B.C. 1122, to about A.D. 1230. After which we have accounts of stars seen in the day-time. These are principally *Venus* and *Jupiter*. Next, an account of auspicious stars, then of temporary stars, and lastly, of extraordinary halos and rainbows.

The observations of solar spots which form the subject of this paper extend from A.D. 301 to 1205, a period of 904 years. They, however, amount to but 45, a number which, considering the time over which they are spread, must appear very small. But it must be recollected that naked-eye observations of the solar spots must of necessity be of very rare occurrence, and, as there is no mention of the employment of coloured or smoked glasses to take off the glare of the Sun, they could only be made under the favourable circumstances of a fog, and the Sun rarely presents us with spots sufficiently large to be seen even then, without optical assistance. Sir John Herschel, in his *Outlines of Astronomy*, remarks that, at least, on two occasions before the invention of telescopes, spots had been seen with the naked eye, and it appears evident to me that these were considered by him as occurrences of a very unusual kind. Here, however, in Ma Twan Lin's work, we have a record of 45 observations of these objects, some of which were seen for several days following. Many of these spots are recorded, as resembling plums of different kinds and sizes, and others are said to have been as large as a hen's egg, and one is mentioned as having resembled a duck. This may remind us of one of the observations of the late Capt. Shea, who describes a group of spots as being like a ship, and also of the drawing of a group of spots exhibited by Mr. Howlett some years ago, which bore a grotesque resemblance to a human skeleton. Most of the instances of their having been seen for several days in succession are within

the bounds of possibility. One, however, which is said to have been seen for 19 days, could never have been observed for that length of time on account of the now well-known period of the rotation of the Sun, and it is singular that no conclusions were attempted to be drawn from the peculiar phenomena thus presented to their eyes, nothing of the kind being to be found in their writings.

These observations are continued in the supplement to Ma Twan Lin's Encyclopaedia, published since the accession of the present dynasty in 1644, in which the subjects treated of in the former work are brought down to the date just mentioned. I have had no opportunity, lately, of consulting this work, but I have found in the history of the Ming dynasty, that which preceded the present one, many observations of the solar spots, the latest being dated Nov. 29, 1638, only six years before the accession of the reigning dynasty, the Tsing. On the present occasion I shall confine myself solely to the observations contained in the original work of Ma Twan Lin. They are possibly of but little value in themselves beyond the mere fact that they were made by the Chinese astronomers at the dates specified, but I must here observe that, as it is stated in our astronomical works, that among Europeans, Galileo in 1610 was the first observer of the solar spots, it follows that the Chinese astronomers were far earlier in their observations of those remarkable objects. In fact, these very observations now placed before you were printed and published in the first edition of Ma Twan Lin's Encyclopaedia, which edition appeared in 1322. I must also express my conviction, founded, after a careful and critical examination, on the peculiar appearance of the characters, the date 1322, the paper and other indications, that in the volumes in my possession, I have really a copy of the first edition of Ma Twan Lin's work, in which opinion I am supported by the Rev. J. Summers, Professor of Chinese, King's College, London. Hence we find that these observations were published 288 years before Galileo's observations in 1610. I may also remark that, as these Chinese observations commence in A.D. 301, their astronomers had detected the spots in the Sun 1308 years before the assumed first discovery by Galileo. It must, however, be observed, that, previous to the commencement of the seventeenth century the intercourse between China and Europe was extremely limited, and little or nothing was known by Europeans either of the language, or of the general literature of that country until towards the close of that century. It was, therefore, next to impossible that Galileo could have known anything of what the Chinese had done so long before him, and he is therefore fully entitled to the credit given him by his contemporaries as regards the solar spots. These circumstances render these early observations of the Chinese historically curious; and if they have no other merit, they tend to establish the fact, with some appearance of certainty, that the physical constitution of the Sun has undergone little or no alteration since A.D. 301 to the present time, a period of 1572 years.

In extracting these observations I have confined myself merely to the year, month, and day of their occurrence. In the original we have the name of the Emperor and other particulars which are not unimportant; all that is required being the correct date, which, in every instance, has been carefully reduced from the Chinese mode of expressing it, to our reckoning, by means of

the tables I published in my work on Chinese cometary observations. To this I have added, where necessary, the incidental remarks relating to the appearance or size of any particular spot, and the number of days, on which it was visible. I have, however, left out the astrological deductions, as in several instances the death of an Emperor, or some other important personage, is said to have shortly followed the appearance of a spot. In short, I have rendered them as concisely as possible, and have only to express my hope that they may not be found entirely useless in the investigation of these remarkable phenomena.

Chinese Observations of Solar Spots from A.D. 301 to 1205, extracted from the *Encyclopaedia of Ma Twan Lin*, vol. lxxxiii, chapter cclxxxiv:—

A.D.		
301	October 20	
321	March 8	
322	March 11	
342	September 3	
354	November 7	Large, like a hen's egg.
355	April 4	Like a peach.
359	September 8	Like a hen's egg.
369	November 3	
370	March 29	Like a large plum.
372	November 30	
373	November 26	Like a small plum.
374	April 6	Like a duck.
374	November 27	Like a hen's egg.
388	April 3	Like a small plum.
389	July 17	Like a small plum.
396	December 8	
400	December 24	
577	December 30	Like a cup.
826	March 25	
852	April 14	
837	December 15	Like a hen's egg.
841	December 31	
874	No month or day	
974	February 2	
1077	March 6	Like a large plum.
1078	March 10	Like a plum. The text says seen for 19 days?
1079	January 11	Like a plum. Seen for 12 days
1079	March 28	Like a plum. Seen for 10 days.
1104	November 12	Resembling a date.
1112	May 3	As large as a chestnut.
1118	November 17	Like a large plum.
1120	July 31	Like a date.
1123	January 5	Like a large plum.
1129	April 21	
1129	December 16	
1131	March 12	Like a large plum. Seen for 3 days.
1136	November 24	Like a large plum. Seen for 10 days.
1137	February 27	Like a large plum. Seen for 10 days.
1138	March 17	Resembling a large date.
1138	November 26	
1186	July 22	Like a date.
1193	December	
1200	August 23	Like a date. Seen for 6 days.
1201	January 4	Like a date. Seen for 12 days.
1205	February 7	Like a date. Seen for 13 days.

REVIEW OF PUBLICATIONS

The Soochow Astronomical Chart,[1] by W. Carl Rufus and Hsing-Chih Tien. 24pp, 4to. Two plates and 6 figs. University of Michigan Press, Ann Arbor, 1945. $2.50.

Astronomy in China, like the history of the country itself, is of great antiquity. Ever since the opening to large scale contacts with the West over a century ago, this interesting subject has engaged the attention of a number of European Sinologists and astronomers, among whom may be mentioned Laplace, de Saussure, Schlegel, Wylie, Williams, Chatley, and others. Their researches have brought forth significant results. However, during the past few decades practically no outstanding publication on ancient Chinese astronomy has appeared. The book under review will undoubtedly be a welcome addition in this field. It should serve as a fresh stimulus for the revival of the study of this fascinating subject.

In the Confucius Temple at Soochow, there were originally four stone tablets engraved by a man named Hsun Yiu in A. D. 1247 during the Sung Dynasty. To-day only two remain. One is a geographical map of China and the other the astronomical chart which is the subject of this book. The two missing tablets are known to contain a city map of Soochow and a chart to depict the fates of emperors.

The inked rubbing of the tablet in question, which contains the star chart and the text underneath it, is reproduced in two plates. In the first part of the book, the authors made a translation of the text and added extensive footnotes. In the latter part, an admirable attempt was made to identify the 1440 odd stars shown in the chart. In this the authors are fairly successful, although many stars were not identified and, in view of the simplicity of the chart, will probably remain obscure. While the chart has been noted and commented upon by several investigators, this is the first time that it has been subjected to a thorough and detailed study.

The text, aside from cosmogonical references and astrological in-

[1] See also Rufus' article on the subject in this JOURNAL, vol. 39, p. 33, 1945, where the chart was published in two plates.

ferences, sums up fairly well the extent of astronomical knowledge in China up to that time. For instance, Heaven is treated as a sphere, the circumference of which is divided into 365¼ degrees, so that one degree represents one day of the sun's circuit around the sky. Its daily rotation with direction of movement is noted. The north and south poles are given correct positions from the place of observation (Kai Feng Fu). The equator (Red Road) intersects the ecliptic (Yellow Road) at 24 Chinese degrees. The daily motions and paths of the Sun (Tai-Yang or the Positive Principle) and of the Moon (Tai-Yin or the Negative Principle) are described, and their diameters given in degrees (1½) though much in error. Sun-spots and comets are noted; the solstices and equinoxes, and the seasons elucidated. The Moon's path (White Road) crosses the ecliptic at 6 Chinese degrees. The phases of the Moon and the causes for the eclipses are explained.

The five classical planets consist of Jupiter (the wood planet), Mars (the fire planet), Saturn (the earth or soil planet), Venus (the gold or metal planet), and Mercury (the water planet). These symbolize the five principal elements of nature.

The star chart is said to contain 1565 stars visible at Kai Feng Fu, Honan Province (Lat. 35°). The authors counted only 1440 stars. No doubt the others were lost during the process of rubbing from the stone tablet. The stars are projected, as was customary with earlier Chinese star charts, on the plane of the equator with the pole at the center. The equator, the ecliptic, and the circles of perpetual apparition (circumpolar) and of perpetual occultation are shown. As usual the entire sky is divided into three great stellar spaces (or compounds) and 28 mansions. The latter, distributed very unequally along the ecliptic, represent the Chinese lunar zodiacs. The divisions are marked by radial lines extending from the inner circle to the outer one. They vary from a fraction of a degree to more than 30 degrees. No satisfactory theory has yet been advanced to explain this remarkable disparity.

The stars are linked, as was the custom, by straight lines into groups to form asterisms. There are 313 groups noted. These stellar patterns are supposed to represent pictorially the beings or objects designated. In this respect the authors specially call attention to the

extent of "idealization" exercised by the Chinese stellar cartographer. The inevitable changing of star positions from original observations to conform to these idealizations, together with the traditional sheer disregard of the difference of stellar magnitudes, make it extremely difficult to identify many of the stars mentioned, as was experienced by the authors. In the chart, the Milky Way (the River of Heaven) is bounded by two irregular lines.

Judging from the extent of astrological references as contained in the text, it would seem that the purpose of the chart was more astrological than astronomical. However, there is certainly enough material of astronomical interest in it to warrant a thorough study by the authors. They translated, explained, and identified wherever possible the stars mentioned in the chart. The results are collected in six tables, listed at the end of the book, which as references should prove useful to future students of Chinese astrography.

On the whole, the translations from the originals are substantially correct and the interpretations illuminating. The book is excellently printed. To the authors congratulations are due upon the successful appearance of the book, which, especially to Dr. W. Carl Rufus who has since departed from us, will ever stand as a fitting memorial to him, whose heart and soul has been close to Oriental people and Oriental culture.

David Dunlap Observatory.

C. S. Yu.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The Telescope on Mount Palomar

People everywhere and in all circles of life are anxious to learn what progress is being made toward the completion of this famous instrument. It is one of the great projects of the Rockefeller Foundation, the President of which is Raymond B. Fosdick. In his Review of the work of the Foundation for 1946 he gives the following authoritative and pleasing information.

The funds for the erection of the giant 200-inch telescope on Mount Palomar in California have been supplied by three Rockefeller boards: The International Education Board, the General Education Board and The Rockefeller Foundation. In 1946 the Foundation made a final grant of $250,000 to complete the project, bringing to a total of $6,250,000 the funds appropriated to the California Institute of Technology for this unique instrument of scientific research.

The first grant was made in 1928. The project presented extraordinary engineering and mechanical difficulties, and a number of years elapsed before successful solutions were found for the problems of casting so large a block of suitable glass, of grinding and polishing it to a curvature within a few millionths of an inch, and of supporting the huge mass of 530 tons so that the telescope could be moved almost without friction to follow the pinpoint of a star across the skies.

The project was delayed more than four years by the war, but the grinding of the mirror is now essentially completed, the supporting structure is ready, and it is expected that final assembly will occur during the summer of 1947, with the whole equipment in operation by the end of the year. This equipment includes not only the 200-inch telescope, but the smaller observatories for the three auxilliary or "scout" telescopes, as well as a dormitory, a power plant, water and gas systems, a small museum and seven cottages for the maintenance staff.

What is the justification for this huge expenditure of money and effort? The answer, in general terms, lies in the unconquerable exploring urge within the mind of man. This new telescope will project man's sight into the universe two times farther than it has ever gone before—to a distance of a thousand million light-years away. It will open up an unexplored sphere 8 times the volume of that which has hitherto been sounded. What lies beyond the limits of our present knowledge? Do the stellar systems extend on indefinitely, or is a boundary finally reached beyond which there are fewer and fewer nebulae? What is the true interpretation of the immense velocity with which all the stellar systems appear to be receding? Is it a pseudo-velocity caused by the curvature of space or by some property of light? Why from the dim frontiers of space do the countless Milky Ways send light that with strange uniformity shifts always to the red end of the spectrum? Since stars and nebulae are vast aggregations of atoms or atomic fragments, reacting on each other under conditions of

pressure and temperature beyond anything that can be duplicated in man's laboratories, what secrets can we learn that will add to our knowledge of fundamental physics?

But this knowledge is dangerous, it will be said. Of course it is dangerous. All knowledge is now dangerous. Indeed, knowledge has always been dangerous. For knowledge means power, and power can be used for evil purposes as well as good. But the answer does not lie in trying to curb science or fix boundaries beyond which intellectual adventure shall not be allowed to go. Such a course, even if it could succeed, would return us to an animal existence in which mere survival was the only goal. The search for truth is, as it always has been, the noblest expression of the human spirit. Man's hunger for knowledge about himself, his environment and the forces by which he is surrounded, gives human life its meaning and purpose, and clothes it with final dignity.

Civilization is not being betrayed by science. The betrayal, if it comes, will be by men who do not know how to use science wisely. The telescope on Mount Palomar is a mighty symbol of man's unique distinction: his aspiration to know. Whether that distinction will become the instrument of his own destruction depends upon how rapidly he can travel the long road towards goals of social organization and moral control that are now only faintly seen on the horizon. C.A.C.

NOTEWORTHY THINGS IN FLORIDA

Among the noteworthy things seen in Florida there may be mentioned, (1) the phenomenal attendance at divine worship, the great majority of the people bearing honourable grey hairs, and men and women being in almost equal numbers; (2) a Shuffleboard Club having almost eight thousand members. The game of shuffleboard is usually associated with the deck of a ship, but it was played on shore upwards of three hundred years ago. A recent book by G. F. Willison, entitled "Saints and Strangers" (N.Y., 1945) gives full and interesting details of the coming of the Pilgrims and of the hardships they endured. One of the most noted of the "Strangers" on the *Mayflower* (1620) was Stephen Hopkins, and in this book there are two references to him and shuffleboard:

Hopkins was more democratically inclined than any of the prominent Pilgrims and had no blind respect for authority as such, having many conflicts with the Plymouth magistrates in later years. He insisted on selling liquor without a licence and more than once was in trouble for his free and easy way with "inferiours", being heavily fined on one occasion for "allowing servants and such to sit in his house drinking and playing shovelboard."—page 141.

"In 1635 Assistant Governor Stephen Hopkins was fined £7 for assault; in 1637, £2 for "suffering servants and others to sitt drinkeing in his house... and to play at shovel board & such like misdemeanors"—page 322.

The words in quotation marks are from original documents.

C.A.C.

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MEETINGS OF THE SOCIETY

AT MONTREAL

During the 1945-46 season the Montreal Centre offered to the public a series of four popular lectures entitled "An Introduction to Stellar Astronomy."

On January 24th, 1946, in the first lecture of the series, Mr. F. DeKinder introduced his audience to "The Constellations"—'the most beautiful show on earth.' Although at first glance the stars on a clear night seem numberless, actually only about three thousand are visible to the naked eye at any one time and therefore it is not too difficult to learn to recognize them.

As a matter of convenience, the stars have been divided into groups or constellations. It was the Arabs who kept astronomy alive during the Dark Ages, which is why we find so many Arabic names among the stars and constellations. Lest the planets be confused with the 'fixed stars', Mr. DeKinder took a moment to explain their constant motion and change in position against the background of stars, urging his listeners to watch the beautiful drama being enacted that month by Mars and Saturn in the constellation of Gemini. He then showed a series of slides, first the aspect of the whole sky at different seasons and then the individual constellations in turn.

On February 21st, 1946, Mr. Henry F. Hall gave the second lecture in the series, "The Stars—Their Nature and Classes". As DeSitter once said, the universe is not empty, but almost. With the exception of our own star, the sun, the stars are so far off that they are still only points of light in the largest telescopes. With the aid of the spectroscope, however, these pinpoints of light tell us considerable. We also have the sun as a source of information for of the 91 known elements, 61 are present in the spectrum of the sun.

"In order to understand a star at all," Dean Hall said, "it is necessary to understand an atom a little" for atoms are the building blocks of the universe. After explaining how the spectroscope shows characteristic lines for each element, he then went on to speak of the Harvard classification of spectral types, giving the chemical composition and surface temperatures of each class and closing his lecture with slides of the Russell diagram and typical spectra.

On March 14th, 1946, Mr. E. Russell Paterson spoke on "The Stars—Their Distances and Motions". He dealt first with what he termed 'the dry stuff'—how one arrives at the various figures and statistics from which certain conclusions can be drawn. For measuring the distances of stars, the parallax method can be used with confidence up to a distance of 500 light-years. Beyond that, other methods, based on the apparent and intrinsic brightness of the star, are employed. The proper motions of stars can be determined by comparing photographs taken at long intervals, while the shifting of the lines of the spectrum towards the red or violet end reveals a star's radial motion.

From statistics gathered by these methods, we find that the solar system is travelling at a rate of twelve miles per second, away from Sirius, towards Vega.

We can also draw conclusions on a much grander scale—that our galaxy contains a hundred thousand million stars, all in motion and each four or five light-years distant from its neighbour; that our galaxy is but one of a hundred million galaxies two million light-years apart; and that these galaxies are spreading out at speeds up to 25,000 miles per second.

On April 25th, 1946, in the final lecture of the series, Mr. J. W. Duffie dealt with "The Stars—Unusual Types". He first spoke of double stars—stars in the same gravitational field, eternally locked together. To demonstrate eclipsing binaries, he had constructed a model which showed how the light would fluctuate as one component passed in front of the other.

With the contagious enthusiasm and intimate knowledge of one who has watched such things for himself, he went on to speak of variable stars—cluster type, cepheids and long period variables—showing slides of the light curves of the different types, explaining how a knowledge of these stars has been a useful tool to the astronomer in determining the distances of remote galaxies, and touching on the work of the amateur variable star observer. Finally he dealt with those strange stars misnamed 'novae' and 'supernovae', which due to some great cataclysmic change, suddenly blaze forth and shine with great brilliancy for a few weeks and then sink again into oblivion.

ISABEL K. WILLIAMSON, *Recording Secretary.*

AT TORONTO

April 9, 1946.—The Society met at 8:00 p.m. in the McLennan Laboratory, Mr. Barker presiding. Minutes of the meeting of March 26 were taken as read.

Two persons were elected to membership in the Society, viz:

Mr. Archie C. Hollis-Hallett, Trinity College, Toronto.

Mr. E. Ronald Niblett, 99 Duke Street, Hamilton.

The President introduced three out-of-town officers of the Society who were present: Dr. A. E. Johns, Hamilton, President of the General Society; Dr. H. R. Kingston, London, past-president of the Society, and Mr. J. W. Duffie, secretary of Montreal Centre.

Dr. Frank S. Hogg took over the chair at the invitation of Mr. Barker and on behalf of Dr. Sidney Smith, President of the University of Toronto, he welcomed the large number of guests and the members from out of town.

Dr. J. F. Heard then introduced the guest speaker, Dr. Roy K. Marshall, director of the Fels Planetarium of the Franklin Institute in Philadelphia, who spoke on the subject "The Stars Brought Indoors—An illustrated story of the planetarium, the modern method of astronomical education and entertainment."

Dr. Marshall commended the Toronto Centre on its endeavours to secure for Toronto the first planetarium in the British Empire. He referred to the Zeiss Planetarium, at present in use in five United States cities, as a school-room of unique type by means of which almost all the fundamentals of astronomy can be explained in one room by use of the one instrument.

Describing the operation of the planetarium instrument and some of the buildings throughout the world in which these devices are housed, Dr. Marshall told how with the planetarium the clock could be turned backwards or forward

26,000 years in 75 seconds. The audience begins to appreciate that there is law and order in the universe, even among inanimate things; and even if the spectator cannot understand a word of the demonstrator's commentary, he still gets a thrill out of the show.

The planetarium lecturer must be something of an actor and must realize his own part in the drama. "And after giving several thousand demonstrations, I still get a lump in my throat when the stars suddenly apepar on the dome of the darkened auditorium. To the person making his first visit, the dramatization of celestial wonders is astounding. The lecturer can't speak for several seconds as the gasps of astonishment and bewilderment fill the room. This picturing of the magnificence of the universe is inspiring and gives the average citizen grander thoughts. I've heard people remark as they leave that never have they heard a better sermon. Even a deaf man can be thrilled although he cannot hear the commentary.

"Education is a by-product, not the main objective. Most visitors come to be entertained but they learn much as the drama of the moon, planets and stars rolls along over their heads," he added. "Looking through a telescope doesn't give any idea of what the sky is really like, but the way the planetarium duplicates nature provides a thrill that can be revealed in no other way."

Every city of a half million population should have such a 'theatre of the skies,' according to Dr. Marshall. "I think a planetarium is a must for Toronto and I believe every citizen should support the proposal of your Society that the British Empire's first star-theatre should be established here. It would be a worthy addition to your other fine cultural institutions."

Mr. A. R. Clute, K.C., Vice-President of the Centre, thanked Dr. Marshall for coming from Philadelphia to address the Society, and the meeting was adjourned.

Monday, April 22, 1946.—The Society met at 8:00 p.m. in the McLennan Laboratory, Mr. Barker presiding. Minutes of the meeting of April 9 were taken as read.

Three persons were elected to membership, viz:

Mr. W. B. Ball, 14 Munro Park Avenue, Toronto.

Mr. J. W. Taylor, 43 Charles Street East, Toronto.

Mr. Alan Edgar Hamblett, West Hill P.O., Ontario.

Dr. Frank S. Hogg, Director of the David Dunlap Observatory, then addressed the audience which included members of the Ontario Education Association's sections on Science, Mathematics and Geography, who were in Toronto for the annual O.E.A. meetings. These teachers, many from out of the city, were welcomed by President Barker and Dr. Hogg.

Dr. Hogg spoke on the topic "See For Yourself!—Astronomical observations which can be made with simple equipment." He demonstrated a variety of devices which can be made for small cost by teachers or students for classroom use. These included optical aids such as lenses, simple telescopes, and the pinhole camera; and measuring devices as the cross-staff, sextant and sun-dial. Dr. Hogg also explained the use of star maps and the Society's "Observer's Hand-

book." The meeting was closed with a demonstration of the Foucault pendulum, by which rotation of the earth is demonstrated.

Dr. A. E. Johns, Hamilton, National President of the Society, informally expressed the thanks of both the members and the O.E.A. visitors, and said Dr. Hogg had presented many ideas which should be of valuable aid to those teaching the elements of astronomy.

Thursday, May 23, 1946.—A special meeting of the Society was held at 8:00 p.m. in the McLennan Laboratory, Mr. Barker presiding. Minutes of the meeting of April 22 were taken as read.

Dr. J. A. Pearce of the Dominion Astrophysical Observatory at Victoria, B.C., brought greetings from Victoria Centre and from several other Centres in the west at which he visited on his way to Toronto for the Royal Society of Canada meeting. He then presented an illustrated address on "Recent Investigations on the Pleiades Cluster," describing not only the history of the interesting star group but some of the newer astronomical research on the Pleiades stars and the nebulosity surrounding them. (A more complete paper on these studies will be published later.)

The Recorder announced that the first of the summer series of open-air observational meetings on the University Campus would follow adjournment of this meeting and that others would be held on four Friday evenings, June 7, July 5, August 9 and September 6, weather permitting.

The meeting was then adjourned.

October 8, 1946.—The Society met at the David Dunlap Observatory, Richmond Hill. Following an hour of observation of the moon through telescopes on the lawn, a short meeting was called to order at 8.30 p.m. in the lecture room, Mr. H. W. Barker presiding.

Dr. Hogg welcomed the members and their guests and regretted that cloud conditions threatened to spoil plans to use the 74-inch telescope for observations. He pointed out it was the first time the Society had visited the observatory since 1940, the meetings having been foregone during the later war years because of transportation difficulties, shortage of staff and priority given war research work which had necessitated closing the institution to the public. Although several members of the staff had been given leave of absence to enlist in the Services, a great deal of work was carried on and 15 research papers were published during the war years. Radial-velocity measures had been made on 1,055 stars, each star representing an average of five photographs of one hour exposure. Studies had also proceeded on variable stars in globular clusters, in all representing a substantial contribution to the body of knowledge on which the known facts of the Milky Way are based.

Dr. J. F. Heard described plans for observing the expected return of the Giacobinid meteors during the week, and told members how they could make useful observations.

Dr. C. A. Chant, director-emeritus of the observatory, related how the Dunlap Observatory had been donated to the University of Toronto by Mrs. D. A. Dunlap as a memorial to her late husband, and he said the whole staff had been grieved at the recent death of the donor.

F. L. TROYER, *Recorder*

The Royal Astronomical Society of Canada

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

1890-1946

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton, London and Windsor, Ontario; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as nearly 1,200 members of these Canadian Centres, there are over 400 members not attached to any Centre, mostly resident in other nations, while some 50 additional institutions or persons subscribe to our publications.

The Society publishes a monthly "Journal" containing about 500 pages and a yearly "Observer's Handbook" of 80 pages. Single copies of the "Journal" or "Handbook" are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 3 Willcocks St., Toronto.

The Society has for Sale:

Reprinted from the "Journal" of the Royal Astronomical Society, 1936-1944.

The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

General Instruction for Meteor Observing, (revised 1940) by Peter M. Millman, 24 pages; Price 15 cents postpaid.

A Yoke Mounting for the Six-inch Telescope, by H. Boyd Brydon, 8 pages; Price 10 cents postpaid.

Setting Up and Adjusting the Equatorial Reflecting Telescope, by H. Boyd Brydon, 25 pages; Price 25 cents postpaid.

Occultations: their Prediction, Observation and Reduction, by H. Boyd Brydon, 76 pages, 1944; Price 60 cents.

In quantities of ten or more copies, a discount of 20 per cent will be allowed. Send Money Order to 3 Willcocks St., Toronto.

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